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INTERNATIONAL TECHNOLOGY CORPORATION

MARTIN MARIETTA ENERGY SYSTEMS

PADUCAH GASEOUS DIFFUSION PLANT

Personnel Exposure Potential to Transuranic Materials at the Paducah Gaseous Diffusion Plant

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RESPONSIVE TO THE NEEDS OF ENVIRONMENTAL MANAGEMENT

REPORT NO. IT/NS-91-109

PERSONNEL EXPOSURE POTENTIAL TO TRANSURANIC MATERIALS AT THE PADUCAH GASEOUS DIFFUSION PLANT

Submitted to:

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EXECUTIVE SUMMARY

Historically, internal dose control efforts and internal dose assessments at the PGDP have been based, primarily, upon controlling exposures to and intakes of uranium. However, the presence of irradiated fuel in the enrichment process for a discrete period of time raised the question of whether these efforts and assessments were sufficient to prevent significant intakes of transuranic elements.

This investigation was initiated for the purpose of assessing the potential for exposure to transuranics by workers at PGDP. Three independent evaluations were performed. For each evaluation, exposure estimates were obtained and compared to a "Significant Exposure" level, which is defined as an intake of 100% of the Annual Limit on Intake for each of the radionuclides of interest, an exposure of 2000 Derived Air Concentration-hours, or a committed effective dose equivalent of 5 rem. The following table shows the results from all three phases of this investigation:

AVERAGE OF EXPOSURE ESTIMATES FROM ALL THREE PHASES

Phase	Basis for Assessment	Fraction of Significant Exposure (Average)
Phase 1	Historical Bioassay	0.20 ± 0.24
Phase 2	Historical Air Data	0.20 ± 0.19
Phase 3	Special Bioassay	0.21 ± 0.22

From this table, and to a reasonable degree of certainty, it appears that the historical uranium-based control and dose assessment protocols were sufficient to prevent a significant intake of or exposure to transuranic materials. While there were a number of assumptions made in each phase of the investigation, all of which have associated uncertainties, the findings from each phase are relatively consistent in magnitude, lending validity to the approach and conclusions reached. Furthermore, the assumptions made were "conservative" in nature, resulting in "upper-bound" estimates of exposure for all three phases, and thereby further increasing confidence in the final conclusion.

1.0 INTRODUCTION

Large quantities of recycled uranium (reactor returns) from various Department of Energy (DOE) programs were introduced into the process feed system at the Paducah Gaseous Diffusion Plant (PGDP) from its start-up in 1952 until the mid 1970s. These reactor returns contained transuranic elements produced during irradiation of the original fuel elements. The most significant of these transuranic materials, from a personnel exposure perspective, are neptunium-237 (^{237}Np), and plutonium-239/240 ($^{239,240}Pu$).

Most of the contaminants were removed during chemical reprocessing, but plutonium and neptunium carried through the uranium recovery procedures were introduced into the cascade during the UF_6 feed process. The amount of transuranic materials in the feed cylinders had been characterized in the past, but recent sampling indicates that transuranic contaminants remaining in process lines may have been higher than previously estimated.

In the mid 1970s, a major effort was initiated to upgrade the PGDP cascade facilities. These improvements included replacement of most of the gaseous diffusion barrier, which occurred after the last recycled uranium had been fed through the plant. This action was assumed to have reduced the transuranic inventory in the process system. However, since historical release surveys were not based upon transuranic release limits, it is not possible to confirm this assumption.

Historically, contamination control efforts throughout the PGDP were designed and implemented, primarily, for control of uranium contamination. In light of the probable presence of transuranic materials as well, the question has been raised as to whether personnel exposure potential from transuranic materials as a result of past and present operations at the PGDP is significant.

The health and safety staff at PGDP contracted International Technology (IT) Corporation to evaluate the potential for "significant exposure" to transuranic materials at the PGDP, and to determine if PGDP operations personnel have, to a reasonable degree of certainty, incurred

"significant exposures" to transuranic materials as a result of past practices. (A "significant exposure" to transuranic materials, for the purposes of this investigation, is equivalent to an intake of 100% of the Annual Limit on Intake (ALI) for each of the radionuclides of interest, an exposure of 2000 Derived Air Concentration-hours (DAC-hours), or a committed effective dose equivalent of 5 rem within one calendar year.)

This document contains a description of the approach followed by IT in assessing the probability of significant personnel exposure from transuranic materials at the PGDP, and the findings and conclusions of this investigation. It is important to note that while it is common practice to assume reasonable and typical assumptions during re-construction or evaluation of individual radiation doses, for the purposes of this assessment, only "conservative" assumptions were used. This practice provides additional assurance that only "upper limit" values result, and that the conclusions are valid to a reasonable degree of scientific certainty.

2.0 APPROACH

Most of the radiological surveillance and internal radiation monitoring data collected over the years at the PGDP were analyzed for the presence of gross alpha activity, with positive results attributed to uranium only. There is little information available on the concentration of the specific alpha-emitting radionuclides which may have been present in the samples. However, limited historical information on the ratio of certain transuranic radionuclides (e.g., ^{239}Pu and ^{237}Np) to uranium of various enrichments exists. The attachment (Historical Isotopic Fractions) contains a synopsis of these data, which are summarized in Table 2-1.

To determine whether historical uranium-based radiological control efforts were sufficient to prevent a significant exposure to transuranic materials, various types of uranium-based surveillance and monitoring data were re-evaluated in light of the general elemental fractions shown in Table 2-1. Three independent evaluations were conducted as part of this overall investigation. These were:

> Phase 1: Re-evaluation of historical uranium-based bioassay results in light of known transuranic/uranium ratios, and determination of the transuranic exposure potential for a hypothetical "average" worker and a hypothetical "maximally exposed" worker.
>
> Phase 2: Re-evaluation of historical gross alpha air monitoring results in light of known transuranic/uranium ratios, and determination of the transuranic exposure potential for a hypothetical "average" worker and a hypothetical "maximally exposed" individual.
>
> Phase 3: Identification of selected PGDP personnel with an elevated probability for intake of transuranic materials due to their work history to participate in a special bioassay study (e.g., isotope-specific measurements of sufficient sensitivity to confirm whether a significant intake of transuranic materials occurred in the past).

It is assumed, for the purposes of this investigation, that if there is consistency in the findings of all three phases, the basic approach for assessing the transuranic exposure potential for PGDP operations personnel is valid. The results for each phase of the

investigation are presented in units of "Fraction of Significant Exposure", for ease of comparison. In other words, if the results of a particular exposure estimate are in units of DAC-hours, that value is divided by the DAC-hour value for a "significant exposure", or 2000 DAC-hours, in order to obtain the "Fraction of Significant Exposure". Likewise, if the results of another calculation are in units of nanocurie intake, that value is divided by the ALI, also in nanocuries, in order to obtain the "Fraction of Significant Exposure". Sections 3.0 through 5.0 of this report contain the findings of the individual phases.

3.0 RE-EVALUATION OF HISTORICAL BIOASSAY DATA (Phase 1)

Historical uranium bioassay data for PGDP radiation workers are extensive. Those available for inclusion in this phase of the investigation span a two year time period and consist of over 13,000 samples submitted at a rate of over 500 samples per month.[1] The average concentration of uranium noted in these 13,000 samples is 4.65 $\pm$ 3.10 micrograms of uranium per liter of urine (PGDP-91).

Because of the relatively small standard deviation in the average concentration, for the purposes of this investigation it is assumed that the rate of excretion of uranium for the *majority* of PGDP workers (e.g., 65%) is normally distributed about the mean concentration of 4.65 micrograms per liter, and falls within the range of 1.55 to 7.75 micrograms per liter. It follows that the maximum monthly bioassay result for an *average* hypothetical worker at the PGDP is represented by the average of the 13,000 historical bioassay concentrations plus 1.645 times the standard deviation in the average (i.e., X_{ave} + 1.645 SD, or 9.75 micrograms of uranium per liter of urine), which encompasses 90% of the 13,000 results. Further, a *maximally exposed* hypothetical worker is represented by X_{ave} + 2.576 SD (i.e., 12.61 micrograms of uranium per liter of urine), which encompasses 99% of the 13,000 bioassay results. Table 3-1 contains a summary of the assumed excretion rates of these three population groups.

It is also assumed, conservatively, that the rate of excretion of plutonium and neptunium by PGDP workers is proportional to the rate of uranium excretion. Therefore, if the concentration of uranium in the historical urinalysis results is multiplied by the known ratio of transuranic materials to uranium for the various percent enrichments of ^{235}U found at the PGDP,[2] the concentration of transuranic materials in urine results. From this re-interpretation of historical bioassay data, the intake of transuranic materials, in units of DAC-hours for the hypothetical workers shown in Table 3-1 can be estimated by:

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1 The routine urine bioassay collection frequency for PGDP workers is monthly, or every 30 days, with samples collected on Monday morning.

2 Bulk materials that are enriched to 0.73% (0.0073) of ^{235}U is considered to be the average enrichment for all materials at the PGDP.

$$DAC\text{-}hrs\ U \times \left[\frac{\%Np + \%Pu}{\%100}\right] \times \left[\frac{DAC(U)}{DAC(NpPu)}\right] = DAC\text{-}hrs(NpPu) = DAC\text{-}hrs(TRU)$$

3.1 Maximum Intake Based Upon a Continuous Exposure Model

In general, PGDP radiation workers have a greater probability of incurring a small but continuous undetected intake of radioactive materials (e.g., chronic, low-level) than an undetected acute intake (workplace surveillance is assumed to have been sufficient to identify unusual occurrences of sufficient magnitude to cause an acute intake). To determine the maximum intake for the majority of PGDP workers, as well as for the "average" hypothetical worker and the "maximally-exposed" hypothetical worker, based upon a continuous intake model, the following assumptions are made:

- The DAC for D-class $^{238,235}U$ is 6.0E-10 microcurie/ml. The DAC for W-class ^{237}Np is 2E-12 microcurie/ml. The DAC for Y-class ^{239}Pu is 2E-12 microcurie/ml (DOE-88).

- The hypothetical worker has monthly urine bioassay results as shown in Table 3-1.

- Of the uranium handled by the hypothetical worker at the PGDP, the percentage of ^{235}U by weight ranges from 0.14 for plant feed, to 2.5 for French Reactor tails, with an average enrichment of 0.73% over a twenty year period ending in 1974 (PGDP-84).

- The mode of internal exposure is a continuous daily intake that is equal in magnitude to the daily excretion (e.g., equilibrium conditions).

- There are 30 days between monthly collection of urine samples.

- The fraction of total uranium excreted that appears in the urine, for continuous intake, is 0.75 (LE-87).

- The daily urine volume for an "average" worker is 1400 milliliters. The average inhalation rate is 1.2×10^6 milliliters per hour (ICRP-74).

- The range of transuranic-to-uranium fractions at the PGDP is 0 to 0.31, taken from Table 2-1.

Table 3-2 is a summary of the exposure calculations for the various enrichments of uranium found at the PGDP, and for the various hypothetical worker populations. Assuming an average ^{235}U enrichment of 0.73% and selecting the most conservative transuranic-to-uranium ratio of 0.31, Table 3-2 shows that the "average" hypothetical PGDP radiation worker is exposed to a maximum of 0.27 of the "significant dose" for transuranics, and the "maximally-exposed" hypothetical radiation worker is exposed to 0.35 of the "significant dose".

3.2 Maximum Intake Based Upon an Acute Exposure Model

As stated previously, the most likely intake scenario for PGDP workers is chronic, low-level intakes. However, if a single event (acute) intake is assumed to have occurred on the day after the previous month's bioassay sample was collected, exposure to both uranium of various enrichments and transuranics may be estimated. For this scenario, the following assumptions were made:

- The mode of exposure is a single day intake that occurred the day after the previous collection of urine for bioassay.
- The number of days between monthly collection of urine samples is 30.
- The fraction of total uranium excreted that appears in the urine thirty days after the date of intake is 1.7E-3 (LE-87). (When class W or Y are considered, with retention fractions of 7.28E-4 and 3.27E-5 respectively, the estimated DAC-hrs per month are considerably higher than those shown in Table 3-3.) This is considered to be a reasonable assumption since the majority of the uranium compounds at the PGDP have a lung inhalation class of D. The feed plant buildings are the primary ones with significant W- or Y-class uranium compounds (PGDP-86).

Table 3-3 shows a summary of these exposure calculations for the acute intake scenario. As expected, the estimates of maximum intake based upon a single acute intake scenario are greater than those estimated for the chronic intake scenario (Table 3-2). However, acute intakes of the magnitude shown in Table 3-3 are not likely because PGDP health physics personnel exercise radiological controls over those plant locations where the probability of substantial intakes of uranium is high (i.e., requirements for posting and respirator use).

Bioassay samples have also been collected from personnel in those locations where the probability of large intakes of uranium existed. Over the past 10 years of operation, health physics control over areas with a greater potential for chronic, low level uranium intakes was less stringent.

4.0 RE-EVALUATION OF HISTORICAL AIR MONITORING DATA (Phase 2)

As was the case for historical urine bioassay results, historical air sampling data from 24-hour continuous air monitors are also extensive. The results of over 2000 samples collected over several months in more than 14 facilities were tabulated for this phase of the investigation.[3] The average of these 2000 results is 0.19×10^{-12} microcurie (gross alpha) per milliliter, with a standard deviation of 1.4×10^{-12}. The relatively large standard deviation is attributable, primarily, to the wide fluctuations in airborne concentrations noted in Building 310. In only three cases did an individual building average exceed the regulatory limit for posting based upon the airborne concentrations of Y-class uranium.

For the purposes of this investigation, the airborne concentration in the workplace of the "average" hypothetical worker, and the "maximally-exposed" hypothetical worker are once again represented by X_{ave} + 1.645 SD and X_{ave} + 2.576 SD respectively, where X_{ave} is equal to the average air concentration in the 2000 historical sample results, and SD is equal to the standard deviation in the average. Table 4-1 contains a summary of the assumed airborne exposure conditions for these three hypothetical population groups.

The number of transuranic DAC-hours to which these hypothetical PGDP workers could be exposed is estimated by:

$$\frac{\textit{Total DAC-hrs}}{\textit{hour}} = \frac{(\textit{Gross-}\alpha\ \textit{activity})(\%U)}{DAC(U)} + \frac{(\textit{Gross-}\alpha\ \textit{activity})(\%Np)}{DAC(Np)} + \frac{(\textit{Gross-}\alpha\ \textit{activity})(\%Pu)}{DAC(Pu)}$$

The following assumptions are used for this analysis:

- The average PGDP worker remains in a radiological area six hours per day, five days per week, 50 weeks per year, for a total of 1500 hours per year.
- The average worker inhalation rate is 1.2×10^6 cm^3 per hour (ICRP-74).
- The isotopic fractions are as shown in Table 2-1.

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[3] The data used for this process included air sample results from 1989 through 1991.

- The DAC for D-class $^{238,235}U$ is 6.0E-10 microcurie/ml. The DAC for W-class ^{237}Np is 2E-12 microcurie/ml. The DAC for Y-class ^{239}Pu is 2E-12 microcurie/ml (DOE-88).

- The PGDP historical continuous air monitor data are representative of "year-around" air concentrations, and there is no significant difference between day-shift concentrations and concentrations at other times of the day.

Table 4-2 shows a summary of this analysis, wherein the "average" hypothetical PGDP radiation worker could have received up to 0.39 of the "significant exposure" for transuranics, as determined from this re-evaluation of historical gross-alpha air monitoring results. Likewise, the "maximally-exposed" hypothetical radiation worker could have received up to 0.60 of the "significant exposure" from transuranics, depending upon the inhalation class of the uranium compound selected.

A population of PGDP employees with the highest probability for intake of transuranic materials due to length of employment, location of work at PGDP, and/or work practices was selected for participation in a "special" bioassay program. From the results obtained, the maximum intake of transuranic materials for various exposure scenarios, can be estimated. This then can be compared to the findings of Phase 1 and Phase 2. In other words, if the intake estimates from special bioassay data for workers with a relatively high probability of intake do not exceed the maximum exposures estimates presented for the hypothetical worker populations, then the approach used for the first three phases of the investigation is assumed to be valid, to a reasonable degree of certainty.

5.1 Technical Basis for Selection of the Special Bioassay Methodology

As stated previously, a "significant exposure" to transuranic materials, for the purposes of this investigation, is equivalent to a single intake of 100% of the ALI. Table 5-1 shows the ALI (ICRP-82) and Dose Conversion Factors (DCF) (DOE-88b) for the transuranic materials[4] of interest at the PGDP.

Therefore, in order to determine if PGDP personnel could have incurred a "significant intake" of these transuranic materials as a result of past practices, the bioassay methodology selected must be capable of detecting that fraction of radioactivity expected to be excreted per day at some time period after intake of one ALI.

Figures 1 through 6 show the relative detection capabilities for various forms of bioassay versus the expected daily excretion of the respective radionuclides for a single intake equivalent to 100% of the ALI. For an intake of one ALI, the expected excretion per day was plotted over various lengths of time. On the same plot is the minimum detectable activity of the bioassay technique. Where the two lines cross is the maximum length of time between intake and measurement that a particular bioassay methodology remains effective.

[4] Inhalation class Y is assumed for the plutonium isotopes, and inhalation class W is assumed for the neptunium isotopes. Ingestion is not considered to be a significant route of intake.

While urine bioassay is generally the methodology of choice for routine monitoring, fecal bioassay can be useful in detecting and quantifying minute inhalation intakes of relatively insoluble forms of radionuclides (e.g., transuranics) at long times after they occur. This is because clearance via the feces is the predominant excretion mode in such a long-term exposure situation. As time goes on, the pulmonary region of the respiratory tract controls the rate of release of an insoluble radionuclide either through clearance into the systemic circulation, or by entrance into the gastrointestinal tract by mechanical clearance (i.e., mucocilliary action and subsequent swallowing).

From the Figures (1-6), it is clear that fecal bioassay with a detection limit of approximately 1.4×10^{-8} microcurie of ^{237}Np or ^{239}Pu per sample provides the greatest likelihood of identifying a single acute intake of these radionuclides that may have occurred at long times prior to sampling. However, while fecal bioassay may be of great value at long times after intake as an aid in estimating residual lung burdens of certain materials, substantial uncertainties exist for such application. This is due, primarily, to complications in interpretation of results. However, the fact that these complications exist does not rule out the potential value of this approach, particularly if certain conditions can be met regarding sample collection. For the purpose of this investigation, if collection instructions are followed by participants, fecal bioassay procedures are considered to be useful for identifying small intakes of ^{237}Np and $^{239, 240}Pu$ that occurred some time ago.

The general approach for this phase of the investigation is straight-forward. Participants in the special bioassay program were selected based upon a series of pre-determined criteria; fecal samples were collected and analyzed for each participant; and the results of analysis were evaluated in light of various exposure scenarios. The following sections contain a more complete discussion of each step.

5.2 Selection of Participants

Through interviews with supervisors and long-term employees, various personnel were determined to have had the highest potential for transuranic exposure. This was based on their work environment, and included personnel involved in operations and maintenance of the feed plant and other associated buildings during the time that reactor tailings were fed. The buildings of interest were C-400, C-409, C-410, C-420 (feed plant and decon), C-340 (uranium metal recovery), C-337, C-335, C-333, C-331, C-360, C-315, and C-310 (process

building). These personnel utilized very little protective equipment or contamination control compared to present-day practices. In addition, most of these personnel had "positive" uranium bioassay results at one time or other during their employment at PGDP.

Personnel selected to participate in the fecal sampling program were chosen based on various criteria relevant to their work at PGDP. Long-term employees were considered, due to the fact transuranics were fed into the cascade between 1952 and mid-1970. In addition, employees that have had jobs that required their presence in environments with significant internal radiation exposure potential were considered (i.e., process maintenance or chemical decontamination). These personnel were also participants in the routine PGDP uranium bioassay program, and these results indicate that past uranium intakes occurred. Table 5-2 contains a description of the participants and their uranium bioassay history.

Each participant in the special bioassay program was provided with an information sheet which compared and contrasted the various forms of bioassay (Appendix A), and with an invitation (Appendix B) to participate in the special bioassay program.[5]

5.3 Collection and Analysis of Biological Samples

To assure that the results obtained from this special bioassay program were reasonably valid, it was necessary to establish certain quality control provisions for sample collection, transport, storage, analysis, and reporting. Fecal samples were collected by all of the participants following a common procedure. Appendix C contains a copy of the instruction sheet issued to each participant.

Samples were transported, by over-night carrier, to an off-site radioanalytical laboratory. To reduce the potential for sample cross-contamination, sample collection began no sooner than Saturday morning after the last Friday of work, and samples were forwarded directly from the participant's home to the analytical laboratory.

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[5] Two control subjects, who were residents of Paducah, Kentucky but had never been employed by the PGDP, were also participants in the special bioassay program. These controls were given identical invitations to participate, collection kits, and instruction sheets as the subject population.

Each sample was analyzed at IT Corporation's Richland Laboratory[6] for isotopic uranium content, isotopic plutonium content, and isotopic neptunium content. In general, the analytical goal was to obtain a minimum detectable activity for each sample that did not exceed 0.03 disintegrations per minute per sample.

5.4 Results

Table 5-3 contains a summary of the analytical results for each of the participants in this bioassay study.

5.5 Interpretation

The average concentrations of uranium, neptunium, and plutonium excreted by the subjects shown in Table 5-3 are 2.05E0 $\pm$ 1.84E0, 6.13E-3 $\pm$ 6.91E-3, and 2.79E-3 $\pm$ 6.71E-3 picocuries/sample, respectively. Using these averages, it is possible to estimate the maximum possible exposure for a "hypothetical" worker excreting uranium, neptunium, and plutonium at the same rates for an acute intake scenario. For this analysis, the following assumptions were used:

- The "hypothetical" worker was involved in a single intake event that occurred one, five, or ten years prior to the date of sampling.
- Since each fecal sample is assumed to be a 24-hour excretion, and since each sample was split in two for non-sequential analyses, the "hypothetical" worker excreted uranium, neptunium, and plutonium at a daily rate of twice the aforementioned average values.
- Intake Retention Fractions used for the analysis are based upon ICRP Publication 30 metabolic models for Y-class uranium and plutonium, and W-class neptunium (LE-87).

The maximum possible exposure based upon these assumptions is shown in Table 5-4. As stated previously, an acute intake scenario is not considered to be especially representative of the most likely exposure conditions at the PGDP. If such a scenario had occurred, elevated uranium excretion would have been readily identified in the routine (monthly) uranium bioassay program.

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6 IT Corporation, Analytical Services, 2800 George Washington Way, Richland, Washington, 99352.

The more likely intake scenario for PGDP workers is considered to be a chronic, low-level intake. Therefore, if this exposure scenario is assumed, the total intake of uranium, neptunium, or plutonium over the exposure period of interest can be estimated by:

$$\textit{Fecal Activity per day} = \frac{I}{T} \int_{t-T}^{t} IRF(t)\, dt$$

where I = intake, T = the exposure duration in days, t = day of first bioassay measurement, and IRF = the intake retention fraction for the 24-hour feces bioassay compartment. Table 5-5 shows a summary of these exposure calculations for a "hypothetical" worker.

6.0 DISCUSSION

The results of the exposure estimates from the three phases of this investigation vary, depending upon the basis for the calculations, assumptions made, and the radionuclide of interest. However, to a reasonable degree of scientific certainty, the overall exposure potential from transuranics for PGDP workers is not significant.

There are a number of uncertainties associated with this conclusion. The following is a listing of just a few conditions which could impact its validity:

- The average of the 13,000 historical uranium bioassay results may not be normally distributed about some mean and thus not generally representative of the uranium excretion rate of PGDP workers.
- The average of 2,000 historical air sample results may not be normally distributed about some mean and thus not generally representative of airborne conditions throughout the PGDP.
- The average isotopic fractions of uranium and transuranics used for the Phase 1, 2, and 3 analyses (e.g., Table 2-1) may not be generally representative of the plant-wide isotopic ratios.[7]
- The 16 individuals selected to participate in the Phase 3 special bioassay program may not be generally representative of a population of PGDP workers with a high probability for exposure.
- Plutonium may not always be present in the various transuranic mixtures found throughout the PGDP, therefore its use as a "tracer" for the presence of neptunium may not be appropriate.

Table 6-1 shows the average of the exposure estimates obtained from each of the three phases of the investigation. The range of transuranic exposure estimates obtained from each phase of the overall investigation overlap. This general consistency in the findings of the separate phases supports the basic conclusion that, to a reasonable degree of certainty, significant (i.e., greater than 100% of the ALI) exposures to transuranic materials were not

[7] The historical ratios used for these analyses were based on information that in some cases was decades-old and non-verifiable.

likely, even though the historical radiological controls in place did not consider the possible presence of transuranics.

It is important to note, however, that the estimates of exposure contained in Table 6-1 reflect the probability for exposure of the PGDP population in general. They do not pertain to individual probabilities. Furthermore, the general conclusions of this investigation are applicable to historical radiological conditions at the PGDP only. These estimated exposure probabilities became invalid after PGDP instituted broader radiological controls, to include the transuranics. As a result, the probability for current exposures is assumed to be notably less.

7.0 SUMMARY AND CONCLUSIONS

Historically, internal dose control efforts and internal dose assessments at the PGDP have been based, primarily, upon controlling exposures to and intakes of uranium only. However, the presence of irradiated fuel in the enrichment process for a discrete period of time raises the question of whether these efforts and assessments were sufficient to prevent significant intakes of transuranic elements. The objective of this investigation was to assess the potential for exposure to transuranics by operational personnel at PGDP, using three separate approaches.

While there were a number of assumptions made in each of the phases, all of which have associated uncertainties, the findings are relatively consistent in magnitude, supporting the basic approach for this investigation and lending validity to the conclusions reached. Furthermore, the assumptions made were "conservative" in nature, resulting in "upper-bound" estimates of exposure for all three phases. If a "significant exposure" is defined as an intake of 100% of the ALI for the transuranics, or an annual exposure of 2000 DAC-hours, it is possible to state, to a reasonable degree of certainty, that the historical uranium-based control and dose assessment protocols were sufficient to prevent a significant intake of or exposure to transuranic materials.

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TABLES

TABLE 2-1
AVERAGE ELEMENTAL FRACTIONS OF TRANSURANICS AND URANIUM

Plant Location	Percent Uranium	Percent Neptunium	Percent Plutonium
Feed plant (general)	100	0	0
Cascade (general)	100	0	0
Bldg. C-333	85.9	11.0	3.3
Bldg. C-720	82.9	16.4	0.7
Bldg. C-337	76.3	22.8	0.98
Bldg. C-400	93.1	6.9	0
Bldg. C-409	76.3	22.0	1.7

TABLE 3-1
URANIUM EXCRETION RATES FOR HYPOTHETICAL POPULATION GROUPS

Hypothetical Worker	Characterization Methodology	Uranium Excretion Rate (micrograms per liter of urine) Used for Analysis
Majority of PGDP Workers	X_{ave} + SD (Maximum value for 65% of the population)	7.75
"Average" PGDP Worker	X_{ave} + 1.645 SD (Maximum value for 90% of the population)	9.75
"Maximally-exposed" PGDP Worker	X_{ave} + 2.576 SD (Maximum value for 99% of the population)	12.61

* X_{ave} is equal to the average excretion rate of 13,000 historical uranium bioassay results.

TABLE 3-2
CHRONIC EXPOSURE POTENTIAL FOR THE HYPOTHETICAL WORKER

Population Group	Radionuclide of Interest	Uranium Enrichment (%)[8]	Range of TRU/U Ratios	Fraction of Significant Exposure
Majority of PGDP workers	Uranium	0.14	NA	0.002
	Transuranics	0.14	0.00 - 0.31	0 - 0.53
	Uranium	0.73	NA	0.002
	Transuranics	0.73	0.00 - 0.31	0 - 0.219
	Uranium	2.50	NA	0.005
	Transuranics	2.50	0.00 - 0.31	0 - 0.459
"Average" worker	Uranium	0.14	NA	0.002
	Transuranics	0.14	0.00 - 0.31	0 - 0.192
	Uranium	0.73	NA	0.003
	Transuranics	0.73	0.00 - 0.31	0 - 0.274
	Uranium	2.50	NA	0.006
	Transuranics	2.50	0.00 - 0.31	0 - 0.574
"Maximally-exposed" worker	Uranium	0.14	NA	0.003
	Transuranics	0.14	0.00 - 0.31	0 - 0.245
	Uranium	0.73	NA	0.004
	Transuranics	0.73	0.00 - 0.31	0.350
	Uranium	2.50	NA	0.008
	Transuranics	2.50	0.00 - 0.31	0 - 0.735

[8] In order to ensure that the findings of this assessment are conservative in nature, the maximum enrichment used for these calculations was 2.5%, since materials of this assay have been received by the PGDP in the past. However, it is important to note that the maximum assay of materials run through the process feed system is 2%.

TABLE 3-3
ACUTE EXPOSURE POTENTIAL FOR THE HYPOTHETICAL WORKER

Population Group	Radionuclide of Interest	Uranium Enrichment (%)	Range of TRU/U Ratios	Fraction of Significant Exposure
Majority of PGDP Workers	Uranium	0.14	NA	0.023
	Transuranics	0.14	0.00 - 0.31	0 - 2.134
	Uranium	0.73	NA	0.035
	Transuranics	0.73	0.00 - 0.31	0 - 3.282
	Uranium	2.50	NA	0.073
	Transuranics	2.50	0.00 - 0.31	0 - 6.784
"Average" worker	Uranium	0.14	NA	0.029
	Transuranics	0.14	0.00 - 0.31	0 - 2.681
	Uranium	0.73	NA	0.044
	Transuranics	0.73	0.00 - 0.31	0 - 4.103
	Uranium	2.50	NA	0.091
	Transuranics	2.50	0.00 - 0.31	0 - 8.479

TABLE 4-1
AIRBORNE EXPOSURE CONDITIONS FOR THE POPULATION GROUPS

Hypothetical Worker	Characterization Methodology	Gross-alpha Airborne Concentration (μCi/ml) Used for Analysis
Majority of PGDP Workers	X_{ave} + SD (Maximum value for 65% of the population)	1.6E-12
"Average" PGDP Worker	X_{ave} + 1.645 SD (Maximum value for 90% of the population)	2.5E-12
"Maximally-exposed" PGDP Worker	X_{ave} + 2.576 SD (Maximum value for 99% of the population)	3.8E-12

TABLE 4-2
EXPOSURE BASED ON CONTINUOUS AIR MONITOR DATA

Population Group	Isotopic Fractions	Uranium Inhulation Class	Maximum DAC-hrs per Hour	Fraction of Significant Exposure
Majority of workers	U - 1.00	Y	0.08	0.080
	U - 1.00	W	0.0053	0.005
	U - 1.00	D	0.0027	0.003
	U - 0.763 Np - 0.22 Pu - 0.017	Y	0.25	0.250
	U - 0.763 Np - 0.22 Pu - 0.017	W	0.19	0.190
	U - 0.763 Np - 0.22 Pu - 0.017	D	0.19	0.190
"Average" worker	U - 1.00	Y	0.12	0.125
	U - 1.00	W	0.0083	0.008
	U - 1.00	D	0.0042	0.004
	U - 0.763 Np - 0.22 Pu - 0.017	Y	0.39	0.390
	U - 0.763 Np - 0.22 Pu - 0.017	W	0.3	0.302
	U - 0.763 Np - 0.22 Pu - 0.017	D	0.3	0.302
"Maximally-exposed" worker	U - 1.00	Y	0.19	0.192
	U - 1.00	W	0.013	0.012
	U - 1.00	D	0.0064	0.007
	U - 0.763 Np - 0.22 Pu - 0.017	Y	0.59	0.600

Population Group	Isotopic Fractions	Uranium Inhalation Class	Maximum DAC-hrs per Hour	Fraction of Significant Exposure
	U - 0.763 Np - 0.22 Pu - 0.017	W	0.45	0.456
	U - 0.763 Np - 0.22 Pu - 0.017	D	0.45	0.456

TABLE 5-1
ALIs AND DCFs

Radionuclide	ALI (μCi)	Rem/μCi intake (CEDE - Inhalation)
^{237}Np	5.4×10^{-3}	4.9×10^{2} (W)
^{239}Pu	1.4×10^{-2}	3.3×10^{2} (Y)
^{238}U	5.4×10^{-2}	1.2×10^{2} (Y)

TABLE 5-2
PARTICIPANTS' JOB AND BIOASSAY HISTORY

Participant Number	Date of Hire at the PGDP	Exposure Duration (days)	Average Historical Uranium Bioassay Results (micrograms/liter)	Maximum (micrograms/liter)
1	August 18, 1968	8420	4.2 ± 5.0	38
2	March 19, 1973	6747	3.4 ± 4.0	26
3	April 8, 1974	6362	7.4 ± 12.7	112
4	July 28, 1968	8442	4.3 ± 6.9	52
5	April 8, 1974	6362	12.6 ± 25.8	256
6	April, 1973	6734	5.3 ± 17.2	124
7	July 16, 1973	6628	16.9 ± 30.7	370
8	April 17, 1972	7084	4.8 ± 6.4	56
9	April 9, 1973	6725	4.2 ± 7.8	47
10	July 16, 1973	6628	5.7 ± 12.0	116
11	August 9, 1971	7335	6.8 ± 17.8	240
12	January 13, 1969	8273	2.3 ± 2.7	18
13	August 6, 1973	6607	3.2 ± 5.6	49
14	February 3, 1953	14092	16.5 ± 19.0	192
15	March 20, 1972	7118	5.3 ± 5.8	32
16	March 11, 1974	6391	14.5 ± 47.1	540
17-C	N/A	N/A	--	--
18-C	N/A	N/A	--	--

TABLE 5-3
SUMMARY OF SPECIAL BIOASSAY RESULTS

Participant Number	Collection Date	^{238}U Concentration (dpm/sample*)	^{237}Np Concentration (dpm/sample*)	^{239}Pu Concentration (dpm/sample*)
1	September 8, 1991	7.08E-1	0.00E+0	1.65E-3
2	September 8, 1991	3.51E+0	1.30E-2	1.17E-2
3	September 8, 1991	1.85E+0	2.30E-2	3.04E-3
4	September 8, 1991	2.16E+0	4.00E-3	1.89E-3
5	September 8, 1991	1.89E+0	1.00E-2	-4.62E-3
6	September 8, 1991	1.48E+0	0.00E+0	-3.35E-3
7	September 8, 1991	1.00E+0	0.00E+0	-2.67E-3
8	September 9, 1991	7.37E-1	4.00E-3	-1.28E-3
9	September 7, 1991	1.32E+0	1.20E-2	0.00E+0
10	September 8, 1991	8.78E-1	1.10E-2	0.00E+0
11	September 8, 1991	1.56E+0	1.00E-2	0.00E+0
12	September 8, 1991	1.45E+0	1.10E-2	1.97E-2
13	September 8, 1991	5.25E-1	0.00E+0	3.20E-3
14	September 7, 1991	3.47E-1	0.00E+0	-3.49E-3
15	September 15, 1991	7.96E-1	0.00E+0	1.24E-2
16	September 9, 1991	5.24E-1	0.00E+0	6.49E-3
17-C	September 8, 1991	7.90E-1	-2.00E-3	0.00E+0
18-C	September 9, 1991	5.40E-1	-2.00E-3	0.00E+0

* Each sample submitted by the participants was assumed to be a twenty-four hour collection of feces. One half of each sample was used for a sequential plutonium/uranium separation and the other half was used for ^{237}Np analysis. Therefore, to obtain a twenty-four hour excretion rate, each result is multiplied by two.

TABLE 5-4
MAXIMUM EXPOSURE BASED UPON ACUTE INTAKE SCENARIO

Radionuclide	Activity in Feces (pCi/24 hours)	Time between Intake and Measurement (days)	Intake Retention Fraction, 24 hour feces	Fraction of Significant Exposure
^{238}U - Y-class	4.10E0	365	8.36E-5	0.908
		1825	1.32E-5	5.760
		3650	1.11E-6	68.334
^{237}Np - W-class	1.23E-2	365	1.37E-5	0.167
		1825	1.76E-6	1.300
		3650	1.64E-6	1.400
^{239}Pu - Y-class	5.58E-3	365	8.44E-5	0.005
		1825	1.40E-5	0.029
		3650	1.75E-6	0.228

TABLE 5-5
MAXIMUM EXPOSURE BASED UPON CHRONIC INTAKE SCENARIO

Radionuclide	Activity in Feces (pCi/24 hours)	Duration of Exposure (days)	Average Intake Retention Fraction, 24 hour feces	Fraction of Significant Exposure*
^{238}U - Y-class	4.10E0	365	7.31E-2	0.379
		1825	4.62E-2	0.615
		3650	7.33E-2	0.378
^{237}Np - W-class	1.23E-2	365	3.68E-2	0.023
		1825	3.97E-3	0.214
		3650	4.09E-3	0.204
^{239}Pu - Y-class	5.58E-3	365	2.43E-2	0.006
		1825	4.58E-2	0.032
		3650	3.59E-2	0.004

* Since the solution to the aforementioned integral was approximated by numerical methods, the variations noted in "Fraction of Significant Exposure" versus exposure duration may be attributed to the division of the integration region into a limited number of time increments.

TABLE 6-1
AVERAGE OF EXPOSURE ESTIMATES FROM ALL THREE PHASES

Phase	Average Fraction of Significant Exposure	Standard Deviation in the Average
Phase 1* - Historical Bioassay	0.201	0.240
Phase 2 - Historical Air Data	0.198	0.187
Phase 3* - Special Bioassay	0.206	0.215

* Average value does not include results of calculations from acute exposure scenarios, which are not considered to be likely intake scenarios for PGDP workers.

FIGURE 6

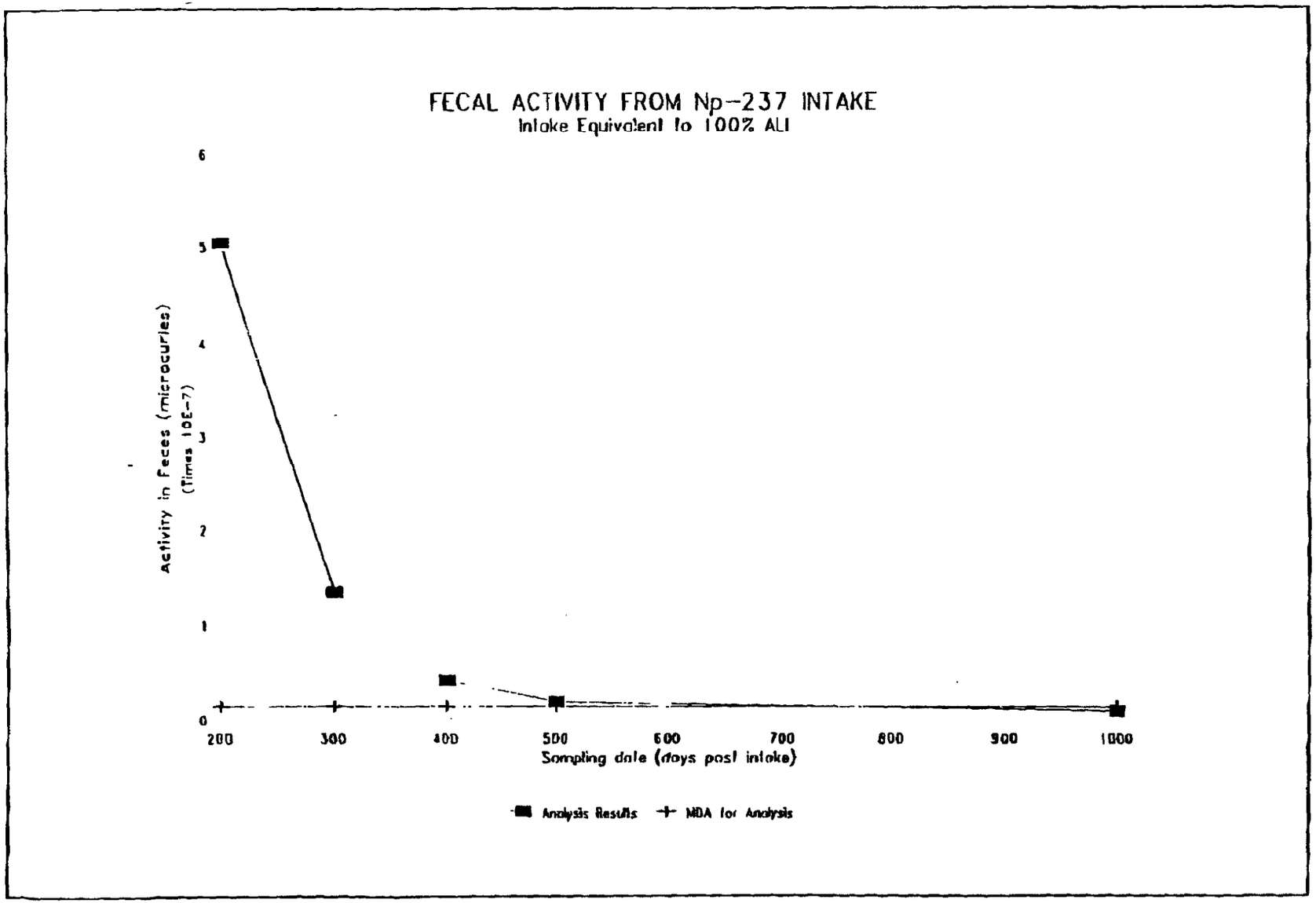

FECAL ACTIVITY FROM Np-237 INTAKE
Intake Equivalent to 100% ALI
Activity in Feces (microcuries)
(Times 10E-7)
0
1
2
3
4
5
6
200
300
400
500
600
700
800
900
1000
Sampling date (days post intake)
Analysis Results
MDA for Analysis

FIGURE 5

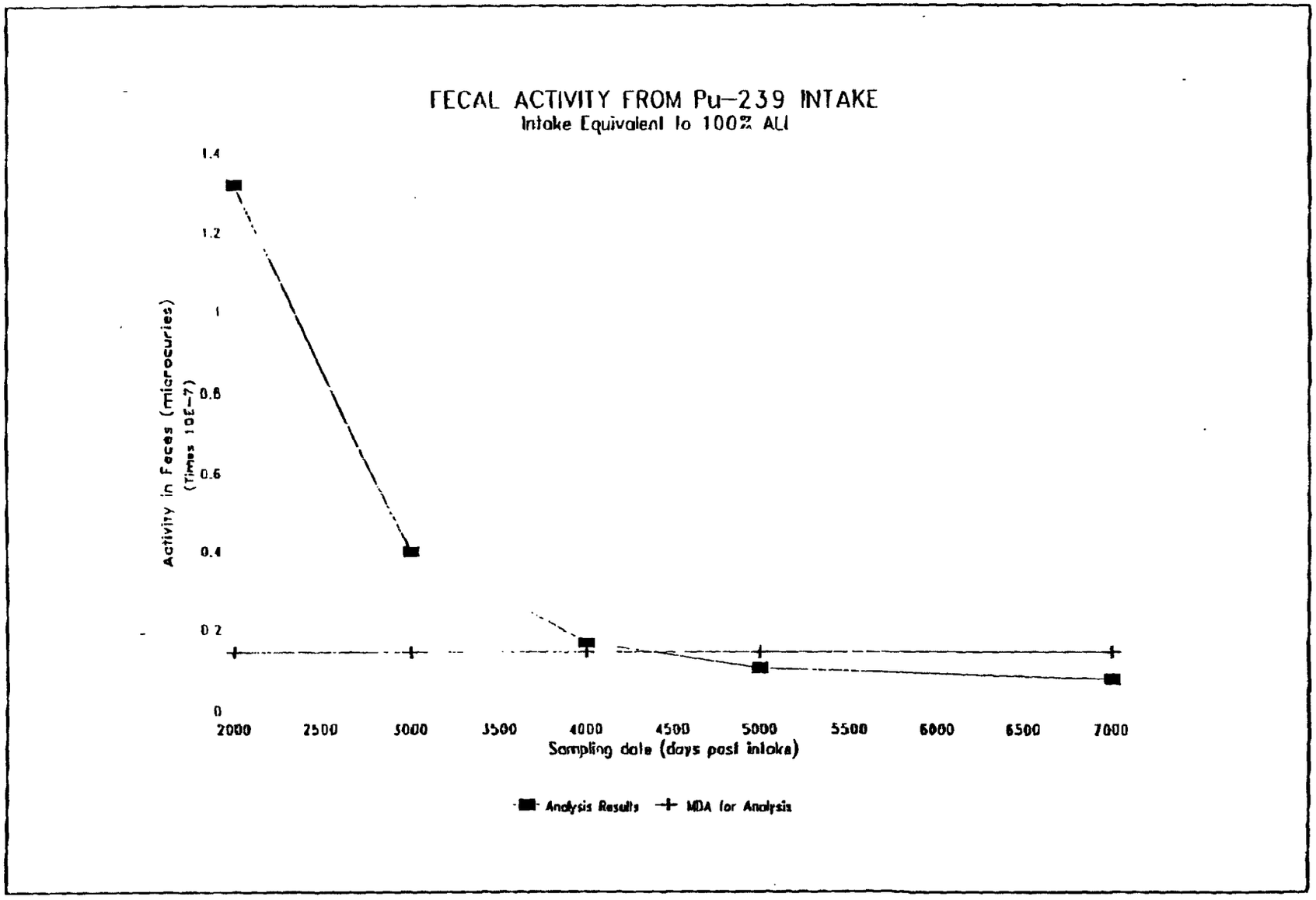

FECAL ACTIVITY FROM Pu-239 INTAKE
Intake Equivalent to 100% ALI
Activity in Feces (microcuries)
(Times 10E-7)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
Sampling date (days post intake)
Analysis Results
MDA for Analysis

FIGURE 4

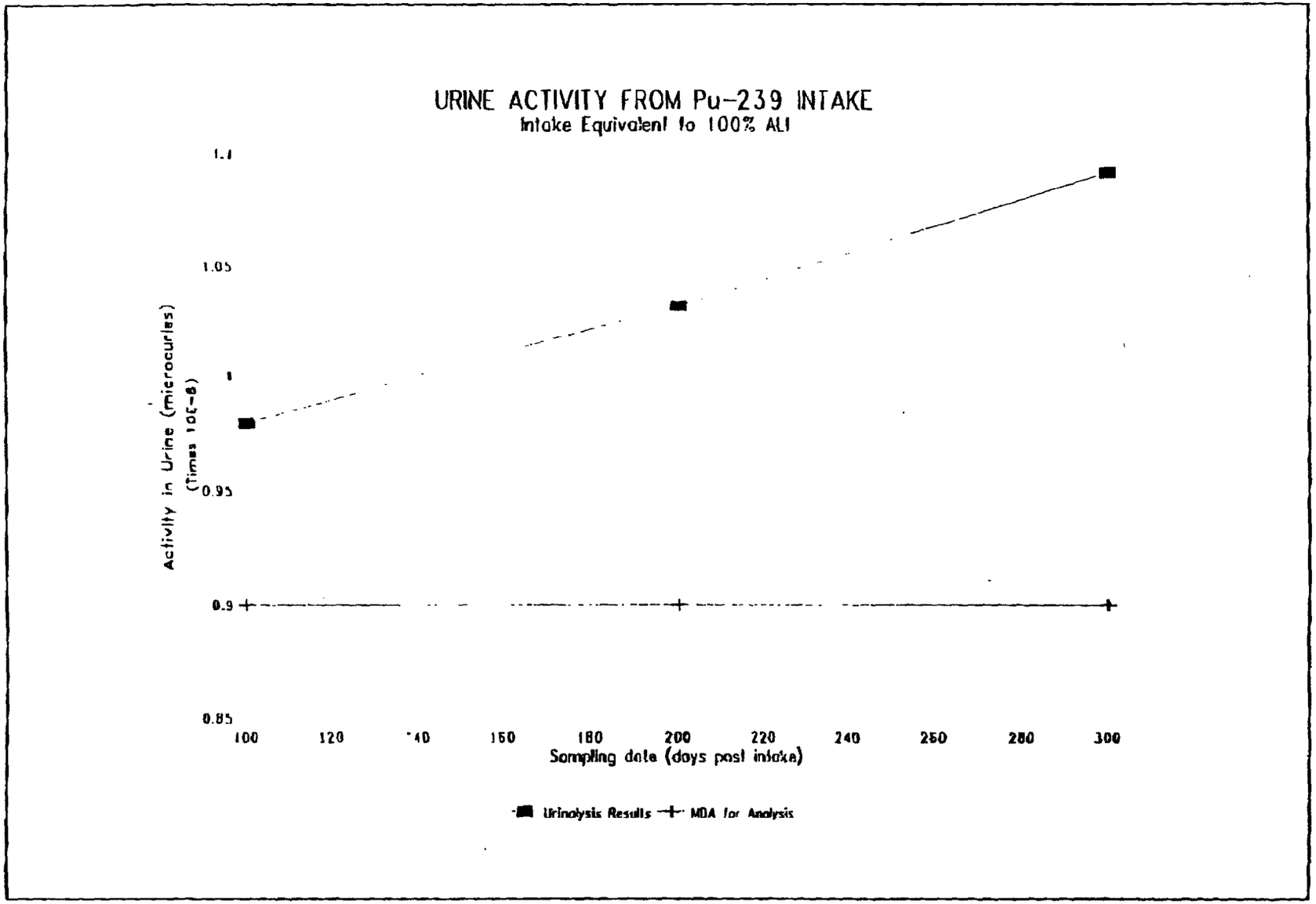

URINE ACTIVITY FROM Pu-239 INTAKE
Intake Equivalent to 100% ALI
Activity in Urine (microcuries)
(Times 10E-6)
1.1
1.05
1
0.95
0.9
0.85
100
120
140
160
180
200
220
240
260
280
300
Sampling date (days post intake)
Urinalysis Results
MDA for Analysis

FIGURE 3

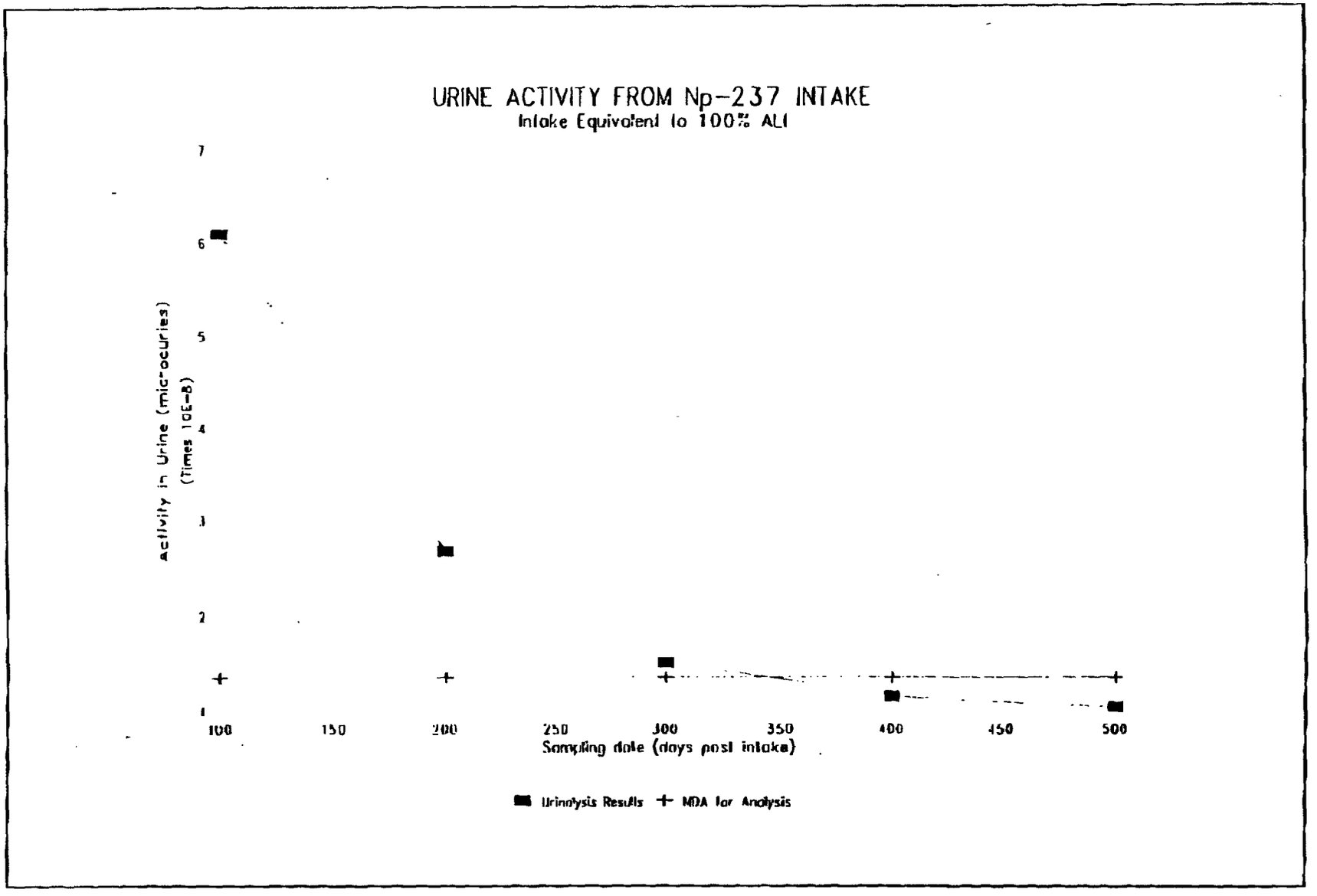

URINE ACTIVITY FROM Np-237 INTAKE
Intake Equivalent to 100% ALI
Activity in Urine (microcuries)
(Times 10E-8)
7
6
5
4
3
2
1
100
150
200
250
300
350
400
450
500
Sampling date (days post intake)
Urinalysis Results
MDA for Analysis

FIGURE 2

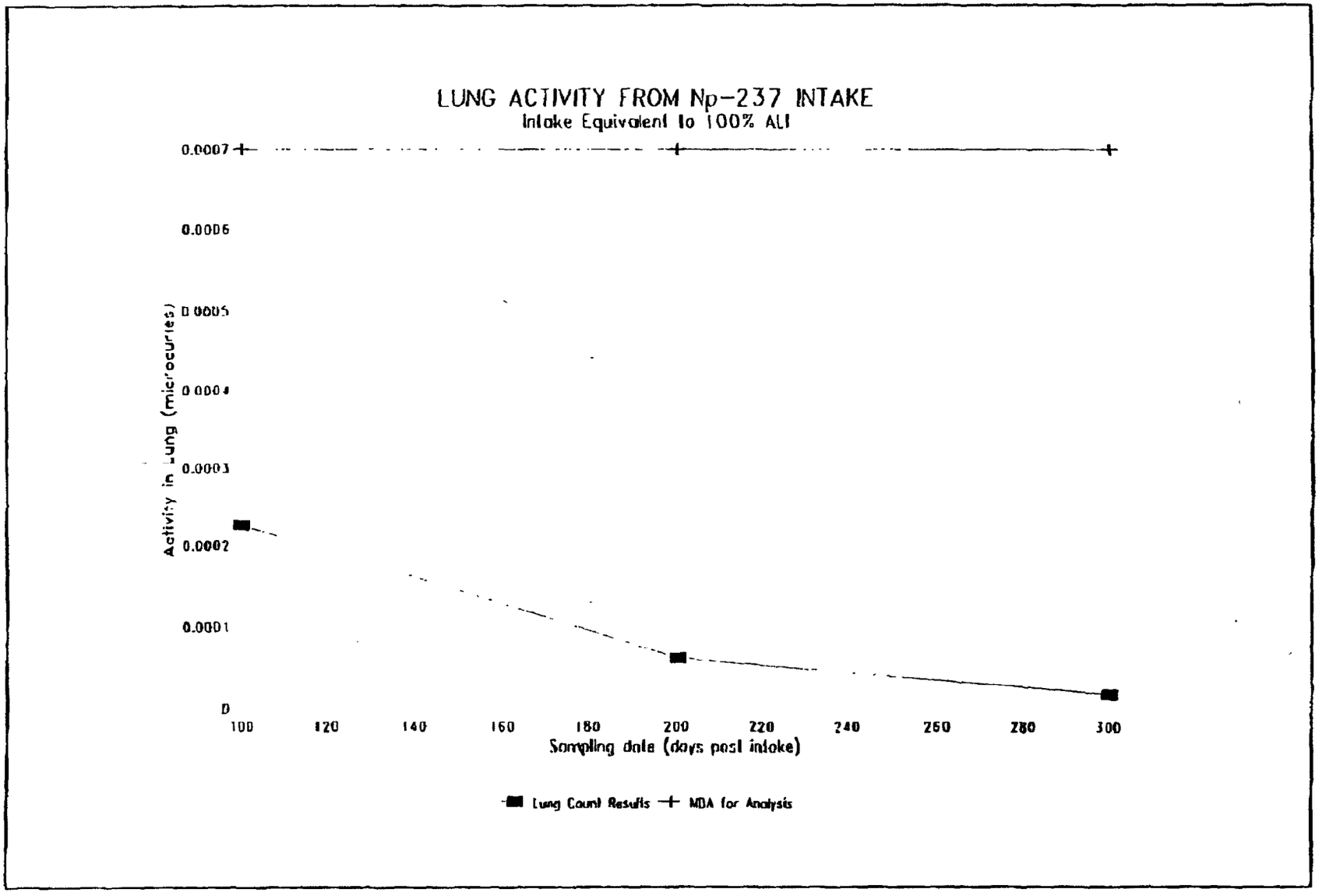
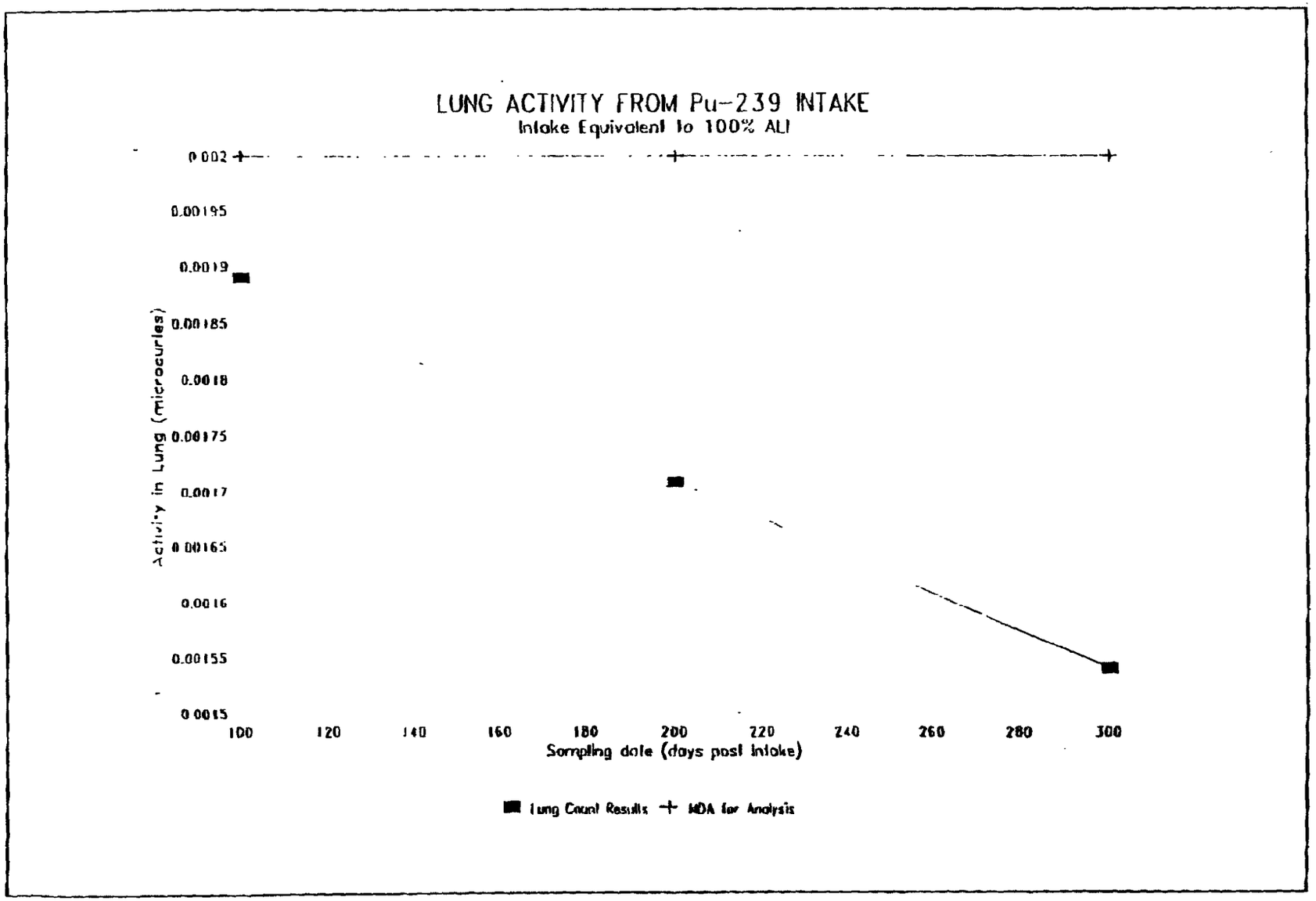

LUNG ACTIVITY FROM Np-237 INTAKE
Intake Equivalent to 100% ALI
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Activity in Lung (microcuries)
100
120
140
160
180
200
220
240
260
280
300
Sampling date (days post intake)
Lung Count Results
MDA for Analysis

FIGURE 1


LUNG ACTIVITY FROM Pu-239 INTAKE
Intake Equivalent to 100% ALI
0.002
0.00195
0.0019
0.00185
0.0018
0.00175
0.0017
0.00165
0.0016
0.00155
0.0015
Activity in Lung (microcuries)
100
120
140
160
180
200
220
240
260
280
300
Sampling date (days post intake)
Lung Count Results
MDA for Analysis

FIGURES

DETECTION CAPABILITIES FOR VARIOUS BIOASSAY METHODOLOGIES

ATTACHMENT

ATTACHMENT
HISTORICAL ISOTOPIC FRACTIONS

Building No.	Np (Percent of total gross alpha activity)	Pu (Percent of total gross alpha activity)	U (Percent of total gross alpha activity)	Reference
C-409	11	3	86	7
	11	3.1	85.9	7
	20	0	80	8
	20	.00062	80	8
	46	6	48	11
	6	0	94	14
	40	0	60	14
C-400	1.7	0	98.3	4
	.05	0	99.5	4
	36.9	0	63.1	4
	0.1	0	99.9	4
	0.3	0	99.7	4
	2.2	0	97.8	4
	8.5	0	91.5	4
	0.9	0	99.1	4
	0.8	0	99.2	4
	0.4	0	99.6	4
	24.0	0	76.0	13
	6.3	0	93.7	14
C-337	20	0	80	8
	20.2	.00062	79.8	8
	30	0	70	9
	0.7	.00002	99.3	10
	18	.001	82	10
	25 6	6.7	67.7	10
	46	6	48	11
	6	0	94	12
	64.3	0	35.7	13
	12.7	0	87.3	13

Building No.	Np (Percent of total gross alpha activity)	Pu (Percent of total gross alpha activity)	U (Percent of total gross alpha activity)	Reference
	6.3	0	93.7	14
	6	0	94	14
	40	0	60	14
C-720	1.8	0	98.2	1
	2.1	0	97.9	2
	2.8	0	97.2	3
	30	0	70	9
	0.69	.01	99.3	10
	18.0	.0001	82.0	10
	25.6	6.7	67.7	10
	6	0	94	12
	64.3	0	35.7	13
	12.7	0	87.3	13
C-333	11	3	86	7
	11.1	3.6	85.8	7
Feed Plant	0	0	100	15
Creek, C-404 Holding Pond	0	0	100	15
Feed Plant by RT to Cascade	0	0	100	16

References:

1 Form HP-7A, "Request for Sample Analysis", March 11, 1991
2 Form Hp-7A, "Request for Sample Analysis", March 12, 1991
3 Form HP-7A, "Request for Sample Analysis", March 14, 1991
4 Memorandum, "Health Physics recommendations for Buildings C-400, C-410, and C-420", from M. B. Graves and A. H. Jeffries to C. W. Walter, May 24, 1990
5 Memorandum, "C-746B Drums Survey", from R. E. Byrd to B. J. Kruger, November 8, 1989
6 R. Baker, "Neptunium-237 Contamination Controls in a Gaseous Diffusion Plant (Draft)", undated.
7 Health Physics Inspection Report, November 4,5,9, 1976
8 Health Physics Inspection Report, January 7,8,15,16, 1976
9 Health Physics Inspection Report, December 22,23, 1975
10 Health Physics Inspection Report, June 2, 1976
11 Health Physics Inspection Report, April 4,8,10,16, 1976
12 Health Physics Inspection Report, September 28,29, 1975
13 Health Physics Inspection Report, December 15-19, 1975
14 Health Physics Inspection Report, June, July, 1975

APPENDICES

APPENDIX A
BIOASSAY INFORMATION SHEET

by

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IT Corporation/Nuclear Sciences

September 2, 1992

There are, basically, two industry-standard methods for detecting the presence of radioactive material in the human body after intake by inhalation or ingestion. These are direct bioassay (whole body counting), and indirect bioassay (excretion analyses).

Whole body counting is a colloquial term for the measurement of the penetrating radiations emitted from radioactive materials that are contained in the human body. This bioassay method can be used to determine the amount of radioactivity present in the body at the time of measurement, but cannot directly determine the amount that was present at some previous time. That quantity must be inferred from the measured body content of the specific radioactive material, followed by application of mathematical models which describe the behavior of that material in the body.

The principal advantages of whole body counting, and the reason it is so widely used for monitoring workers at nuclear facilities, is that it provides a direct measurement of the radioactivity deposited in the body. Its advantages over indirect bioassay analyses are that (1) it is in general more accurate when there is enough radioactive material in the body to permit its use; (2) it can measure insoluble materials which have entered and been retained in the body and are not readily excreted; (3) it does not involve lengthy analytical procedures; (4) the total body content of radioactive materials is available at the time of the measurement without the use of mathematical models; and (5) the body content of more than one type of radioactive material can be determined simultaneously.

There are also a number of disadvantages of whole body counting. The first of these is its limited detection sensitivity compared to many indirect bioassay procedures. In general, much lower levels of radioactivity can be detected in an excreta sample than can be detected in a whole body count. A second disadvantage is that whole body counting cannot easily tell the difference between radioactive material deposited inside or outside of the body.

Indirect bioassay, or excretion analyses, refers to identifying and quantifying radioactive materials that are excreted or removed from the body. Indirect bioassay procedures are used routinely in radiation protection work to monitor personnel for possible accidental intakes of radioactive materials. After an intake has occurred by inhalation or ingestion, a portion of the radioactive material will be absorbed into the bloodstream and deposited in various body organs or tissues or excreted from the body. Therefore, by analyzing an individual's excreta, an *indication* of whether an intake has occurred can be obtained. Examples of excreta that can be used for indirect bioassay include urine, feces, tissue, blood, fingernails, hair, teeth, saliva, sweat, and breath. However, for most routine internal radiation monitoring programs, urine bioassay is the methodology of choice.

It is important to remember that analysis of radioactivity contained in urine, feces, or other excreta is only an *indirect* measurement of how much radioactive material is present in the body at the time of sampling. It provides no *direct* information on the distribution of the material within the body, the time of exposure, the magnitude of initial uptake, or the cumulative radiation dose resulting from the intake. Mathematical models must be used to estimate much of this information. Uncertainties in these

models are a large part of the overall uncertainty in indirect bioassay results.

On the other hand, as time passes and the body begins to excrete radioactive materials retained by various organs, standard indirect bioassay procedures can detect the presence of smaller amounts of radionuclides than is possible by standard whole body counting techniques, even though, as stated previously, positive results can be more difficult to interpret. This difference in detection capability becomes even greater when insoluble radioactive materials are involved.

While urine bioassay is the methodology of choice for routine monitoring, fecal bioassay can be useful in detecting and quantifying minute inhalation intakes of relatively insoluble forms of radionuclides at long times after they occur. This is because clearance via the feces is the predominant excretion mode in such a long-term exposure situation. As time goes on, the pulmonary region of the respiratory tract controls the rate of release of an insoluble radionuclide either through clearance into the systemic circulation, or by entrance into the gastrointestinal tract by mechanical clearance (i.e., mucocilliary action and subsequent swallowing). However, while fecal bioassay may be of great value at long times after intake as an aid to estimating residual lung burdens of certain materials, substantial uncertainties exist for such application, primarily due to complications in interpretation of results. Nevertheless, these complications do not rule out the potential value of this approach, particularly if certain conditions can be met regarding sample collection.

In an effort to investigate the possibility that minute intakes of transuranic materials (i.e., plutonium and neptunium) may have occurred some time ago for selected PGDP employees, fecal bioassay has been determined to be the measurement method of choice, due to its greater sensitivity for detection of long-lived, tenaciously-retained radionuclides.

For further information on direct and indirect bioassay, the reader is referred to the following documents:

1. Toohey, R. E., Palmer, H. E., Anderson, L., Berger, C. D., Cohen, N., Eisele, G., Wachholz, B., and Burr, W., "Current Status of Whole Body Counting as a Means to Detect and Quantify Previous Exposures to Radioactive Materials", *Health Physics*, Vol. 60, Sup. 1, pp. 7-42, 1991.

2. Boecker, B., R. Hall, K. Inn, J. Lawrence, P. Ziemer, G. Eisele, B. Wachholz, and W. Burr, "Current Status of Bioassay Procedures to Detect and Quantify Previous Exposures to Radioactive Materials", *Health Physics*, Vol. 60, Sup. 1, pp. 45-100, 1991.

3. "Performance Criteria for Radiobioassay", American National Standards Institute, Report No. ANSI N13.30, 1987.

4. "American National Standard for Internal Dosimetry for Mixed Fission and Activation Products", American National Standards Institute, Report No. ANSI N343, 1978.

5. "Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition", National Commission on Radiation Protection and Measurement, NCRP Report No. 87, 1986.

APPENDIX B
INVITATION TO PARTICIPATE

Historically, radioactive contamination control efforts at the Paducah Gaseous Diffusion Plant (PGDP) were designed and implemented primarily for control of uranium contamination. Transuranic contamination (i.e., contamination with radioactive materials whose atomic numbers are *greater* than the atomic number of uranium) at the PGDP became an issue when reactor returns from various Department of Energy (DOE) programs were introduced into the process feed system between 1952 and mid-1970. Most of the contaminants were removed during chemical reprocessing, but plutonium and neptunium carried through the uranium recovery process and were introduced into the cascades during the UF_6 feed process.

In the mid 1970s, a major effort was initiated to upgrade the PGDP cascade facilities. Improvements included replacement of most of the gaseous diffusion barrier. This occurred during the time the last transuranic material was fed and after the last recycle of uranium had been fed through the plant. Removal of the barrier was assumed to have reduced the transuranic inventory in the process system, but there are no data which indicate that the surveys were compared to transuranic release limits.

However, the fact that reactor returns were used at all at the PGDP raises the following questions about personnel exposure potential to transuranic materials as a result of past and on-going operations:

1. To a reasonable degree of certainty, have PGDP personnel incurred significant internal exposures to transuranic materials as a result of their involvement in past operations?

2. To a reasonable degree of certainty, are PGDP personnel currently being exposed (internally) to transuranic materials in their work environment?

One approach for determining if PGDP personnel have incurred significant internal radiation exposures from intake of transuranic materials as a result of past or present practices (Question 1) is to identify a population of PGDP employees with the highest probability of intake of these radioactive materials due to length of employment, location of work at PGDP, and/or work practices. Study of the radionuclides currently contained in the bodies of that population can be used to calculate the maximum possible intake and maximum possible dose for various exposure scenarios.[9] The answer to Question 2 will follow in turn from the results of these calculations, and from analysis of historical internal radiation monitoring data.

You have been selected by the PGDP Health Physics Department as a possible participant in such a study. Your willingness to enter this program will contribute to a greater understanding of the past and present radiological environment at the PGDP, and will contribute to the on-going efforts on the part of the PGDP Health Physics Department to improve the overall radiation protection program.

For your information, International Technology (IT) Corporation is a full service radioanalytical and consulting company, which offers complete radiological support services to both commercial and government institutions. IT specializes in performance of a wide range of bioassay and environmental analyses, which include the measurement of transuranic materials in soil, air, and humans. Our laboratories currently provide both direct (whole body counting) and indirect (excretion analyses) bioassay services to a number of clients. The senior staff members of IT's Nuclear Sciences Division are nationally and internationally recognized experts in the field of radiation protection, and are certified by the American Board of Health Physics.

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9. Given the excretion rate, the body burden for transuranics can be determined. This body burden can in turn be used with a number of intake scenarios to determine doses to individuals.

IT has been contracted by the management of the PGDP to implement and administer a bioassay program, and to attempt to answer Questions 1 and 2, above. IT's participation will include: program specification; assistance in sample collection and transport; sample analysis; validation of results; and generation of a final report, to include interpretation of all data acquired.

Based upon an initial evaluation of possible exposure circumstances at the PGDP, IT has determined that fecal bioassay is the best measurement methodology for this study, since it is the most sensitive means of detecting minute quantities of transuranic material in the human body at long times after intakes have occurred. This capability is not achievable with any other standard bioassay procedure, such as whole body counting. For further information on the differences between various bioassay procedures, and the means by which we determined the most appropriate bioassay technique for this screening program, we refer you to a brief topical report which is enclosed in this package.

Also enclosed in this package is a job history sheet, which you should fill out as completely as possible if you choose to participate in this program. (If you wish a copy of the completed sheet will be sent to you.) In addition, a fecal collection kit and a complete set of instructions for use are included. The instructions contained in the kit require only that you complete the job history sheet and collect a large volume of your feces over a weekend. Return mailing of the sample and associated paper work directly from your home is pre-arranged and pre-paid. After the sample is received by IT's laboratory, and after the analysis is complete, we will provide you with a copy of the results.

As part of our project-specific quality control program, a small fraction of the participants in this study have been selected from the general Paducah, Kentucky population -- in other words, they have not worked at the PGDP. (These individuals are referred to has the "control population". PGDP employees are referred to as the "subject population".) In addition, if the integrity of any sample received by the IT laboratory is breached as a result of mailing or any other reason, we may ask you to submit a second sample. If this should occur, we will send you a synopsis of all actions taken, including all analytical results, and the reasons for any re-sampling that may be required.

Before you decide if you wish to participate in this study, you are encouraged to review each of the items contained in this package. It is critical that each participant follow all of the instructions carefully in order to assure that all final conclusions are reasonably valid. Therefore, if you have any questions about this program, your responsibilities, or any other issue, either now or after your decision to participate has been rendered, you are encouraged to contact one or both of the following individuals:

Kenny Duncan
PGDP Health Physics Department
(502) 441-6411

Carol Berger
IT Corporation/Nuclear Sciences
(202) 331-8510

You will be kept informed of all actions taken in this effort, and you will be provided with a copy of the final report.[10] We hope you will give serious consideration to participating in this important investigation.

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[10] While the final report will contain all of the details of this study, the identity of the participants will be kept strictly confidential.

Enclosures:

Check all items contained in the kit for your correct name and Social Security number ***BEFORE*** *collecting a sample.* ***DO NOT USE*** *this kit or any item contained in it if it does not have your name marked on it.* ***The*** *entire kit should consist of the following items:*

a. Blue Job History Sheet.

b. Yellow Instruction Sheet.

c. White information report entitled, "Selection of the Proper Bioassay Technique for Identification of Possible Intakes of Transuranic Materials in Personnel at the Paducah Gaseous Diffusion Plant".

d. Stamped, return-mail envelope.

e. Fecal sample collection kit containing:

   i. Plastic tub
   ii. Plastic tub liner
   iii. Tamper-evident seal
   iv. Plastic frame

f. Completed Federal Express airbill

g. Completed two-part (white and yellow) IT Corporation "Request for Analysis" form

APPENDIX C
INSTRUCTIONS FOR COLLECTING A FECAL SAMPLE

Name: _____

Social Security No.: _____

You have been given a fecal sample collection kit for your use as a participant in a bioassay study program. ***Do not transfer this kit to any other individual.*** The following are the instructions for use:

1. Wash your hands carefully prior to voiding. Use the disposable collection container when you void. Collection should not begin before Saturday morning.

2. Write down the date and time of your voiding into the collection container here:

_____ _____

Date (month/day/year) Time (a.m.)

3. To collect your feces:

   a. Remove the plastic tub and the plastic frame from the collection kit. Remove the lid from the plastic tub, and insert the tub into the hole of the frame. ***Be sure the top of the plastic tub liner is folded over the top of the plastic tub. Do not remove the plastic tub liner from the plastic tub.***

   b. Pull up the toilet seat and place the frame directly on the toilet bowl, with the wide end towards the rear. Put the toilet seat down on top of the frame to hold it in place. ***A large-volume sample is important for this study.***

CAUTION: The fecal sample must not contain urine.

4. Once the sample is collected, remove the tub and frame ***carefully*** from the toilet bowl. Remove the top of the plastic tub liner from the rim of the plastic tub, seal, and fold over the sample. Place the lid securely on the plastic tub, and place the tamper-evident seal over both the lid and the tub. Package the tub and the white/yellow "Request for Analysis" form in the cardboard box, making sure the Federal Express air bill is carefully secured on the outside of the box.

5. Call the Federal Express office (1-800-238-5355) and arrange for a pick-up on Monday.

6. Place this sheet and the completed blue Job History sheet into the stamped envelope and mail by U.S. mail to IT Corporation.

7. All results will be forwarded to you once analysis is complete. If you have any questions, please contact either Kenny Duncan (PGDP Health Physics Department) at (502) 441-6411, or Carol Berger (IT Corporation/Nuclear Sciences) at (202) 331-8510.

PLEASE FOLLOW ALL INSTRUCTIONS CAREFULLY!